Partial Support of Joint USGS-CALTECH Southern California Seismographic Network

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INVESTIGATIONS

This Cooperative Agreement provides partial support for the joint USGS-Caltech Southern California Seismic Network (SCSN) and the Southern California Earthquake Data Center (SCEDC). The purpose is to record and analyze data from more than 12,492 local earthquakes, from October 2004 to September 2005, and generate a database of phase data and digital seismograms (Figure 1). The primary product derived from the database is a joint USGS-Caltech catalog of earthquakes in the southern California region and the associated waveforms. We maintain the SCSN and SCEDC infrastructures. We also provide rapid response to emergency services, the media, and public inquiries about earthquakes and data for seismological research.

For more detailed information about data access, please contact:
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RESULTS

Network Operation

The SCSN operation of network infrastructure consists of: 1) operating computer and communications hardware/software and other instrumentation for data acquisition at the central site; 2) installation and field maintenance of new and existing digital stations; and 3) population and maintenance of earthquake databases. Caltech and USGS personnel share these operations

responsibilities. Because the SCSN is a cooperative project of Caltech and USGS, all the facilities listed below are jointly operated and contribute to the overall project mission.

Central Site. The SCSN (formerly TriNet and TERRAscope) differs from most regional networks in both size and data processing approach. Most of the data are transmitted using digital communications, products are generated in near-real-time, and automatically archived in an Oracle database.

We lease frame relay from SBC and Verizon for data communications. This includes more than 120 frame relay drops, over 30 "last mile" radio links, 20 "last mile" optical fiber links, and three T1 lines transmitting the data from the frame relay cloud into the Caltech campus. Through agreements with the local utilities, we operate three T1 microwave links that provide wireless data transmission for about 40 stations using their statewide microwave systems.

The data from approximately half of the analog short period stations are digitized at six different remote earthworm hubs. The remaining stations are transmitted via analog phone lines and the USGS microwave to Caltech and digitized at the central site.

Two SUN servers, with 4 CPUs each, operating in primary and backup mode, perform the real-time data acquisition and processing. To improve robustness, these two servers and related equipment are located in two different buildings on campus, the Seismo Lab and the USGS building (525 So. Wilson Ave). Two SUN servers are used for software testing and development. ShakeMap is generated using a SUN server and will also be produced in the future using a 2 CPU LINUX server.

Both parametric and waveform data are archived automatically in the oracle database. The data analysts review and modify the already archived data in the Oracle database. A significant part of our effort is also the maintenance of existing data archives and station metadata for the stations recorded by SCSN.

The major software components used by SCSN are TriNet C++, Perl scripts, and Java software, earthworm modules, and commercial software such as Oracle, and SmartSockets. This software requires extensive maintenance because software and hardware need to be upgraded simultaneously, requirements such as station metadata may change and send ripples through the software. Further, improvements in seismological algorithms may need to be incorporated as errors or improvements are discovered.

SCSN. The SCSN operates 160 broadband and strong motion real-time digital stations, 30 real-time strong motion stations, and about ~120 short period stations to maintain the detection threshold of M1.8 in southern California (Figure 2). The existing digital stations of TERRAscope are part of SCSN.

Broadband and strong motion sites, provide flat instrument response from 50 Hz-30 seconds or greater. Approximately two thirds of the broad sensors have low frequency response to 120 or 360 seconds. They are sited, away from structures of two or more stories, and preferentially at sites with low ambient ground noise. At present we operate 155 broadband and strong motion stations and record data from 10 Anza network stations, 3 University of California borehole stations located on the major campuses, and 4 SCEC borehole strong motion stations.

Strong motion reference sites, differ from traditional free field sites. The reference sites must provide flat instrument response in acceleration and on scale recording up to 2 g. In some cases these sites will also have a broadband seismometer. They will be sited away from structures of 2 or more stories but are located near major facilities or near groups of significant structures. Nearly all of the SCSN stations are either reference sites or free field sites. All strong motion sites have local recording. At present we receive signals from 15 Caltech operated K2's.

Short period sites, that have a single vertical component seismometer, are needed to ensure the minimum magnitude threshold of M1.8. These are quiet sites that provide resolution down to ambient ground noise.

State of health, we monitor the state of health of the network using SeisNetwatch. SeisNetwatch can be operated remotely using a regular web browser and field engineers can be notified via paging or email in case problems develop. SeisNetwatch is a good example of how the seismic network community has benefited from TriNet development. Initially, it was developed as TriNetwatch and was made available to the community as SeisNetwatch at the request of the USGS earthworm group in Golden Colorado.

Data transmission. The SCSN data are transmitted to Caltech via frame relay, digital microwave, Internet, and spread spectrum radio. We lease three T1 frame relay lines from Pacific Bell, which terminate at Caltech. At six locations, we collect several stations before the data are put onto frame relay lines, with three stations sharing a single frame relay line. Connecting to remote sites, we lease more than 120 frame relay circuits. For communications we operate, two 3 T1 capacity CISCO routers, a Motorola router, and several terminal servers. We also operate a 2 T1 capacity digital microwave link to Mt. Lukens to connect to the So Cal Edison and City of Los Angeles Department of Water and Power wide area networks. Further, we operate a third last mile microwave link to Verdugo Peak for data transmission from sites located at Southern California Gas Co. sites.

Seismicity Summary for Southern California

October 2004 - September 2005 Southern California events processed & distribute during the reporting period (October 1, 2004 through September 30, 2005):

12,492	earthquakes (inside & just outside of our region) & quarry blasts, of which
1,660	were magnitude 2.0 or larger, of which
180	were magnitude 3.0 or larger, of which
26	were magnitude 4.0 or larger.
600	of the above events were mine or quarry blasts.

The twelve magnitude 4+ quakes are listed below:

MAG	YYYY/MM/DD	HH:mm:SS	LAT	LON	DEP	LOCATION
4.2	2004/11/13	09:39:16	34 21.2 N	116 50.7 W	09.6	10 km (6 mi) N of Big Bear City
4.0	2005/01/02	12:58:48	32 20.8 N	115 13.4 W	06.0	44 km (27 mi) SE of Calexico
4.4	2005/01/06	06:35:27	34 07.5 N	117 26.3 W	04.2	02 km (1 mi) N of Fontana
4.3	2005/01/12	00:10:46	33 57.2 N	116 23.7 W	07.6	10 km (6 mi) E of Desert Hot Springs
4.1	2005/02/02	05:17:39	31 56.3 N	116 13.4 W	06.9	91 km (57 mi) SSW of Ocotillo
4.2	2005/02/15	14:23:27	31 38.9 N	115 58.3 W	03.9	121 km (75 mi) S of Ocotillo
5.2	2005/04/16	12:18:13	35 01.6 N	119 10.7 W	10.3	22 km (13 mi) W of Wheeler Ridge
4.3	2005/04/19	11:17:59	31 31.0 N	115 32.9 W	06.0	128 km (80 mi) S of Calexico
4.0	2005/04/20	23:36:19	33 39.4 N	120 02.0 W	06.0	33 km (20 mi) SSE of Santa Rosa Is.
4.1	2005/05/05	19:29:09	35 01.8 N	119 10.9 W	11.6	22 km (14 mi) W of Wheeler Ridge
4.1	2005/05/20	17:39:32	33 13.4 N	116 12.3 W	15.1	11 km (7 mi) NW of Ocotillo Wells
5.2	2005/06/12	08:41:46	33 31.7 N	116 34.4 W	14.2	10 km (6 mi) ESE of Anza
4.9	2005/06/16	13:53:26	34 03.5 N	117 00.7 W	11.6	3 km (2 mi) NE of Yucaipa
4.0	2005/06/27	15:17:33	34 03.3 N	117 01.8 W	12.1	2 km (1 mi) N of Yucaipa
4.1	2005/07/24	05:59:42	33 40.4 N	119 45.7 W	06.0	44 km (27 mi) SE of Santa Rosa Is.
4.3	2005/08/05	22:40:33	36 08.4 N	118 02.7 W	00.0	14 km (8 mi) NW of Coso Junction

4.6	2005/08/31 15:47:45	33 09.9 N 115 38.1 W 04.0	1 km (0 mi) S of Obsidian Butte
4.5	2005/08/31 15:50:24	33 10.3 N 115 36.7 W 02.0	2 km (1 mi) E of Obsidian Butte
4.1	2005/08/31 16:07:16	33 10.5 N 115 37.1 W 04.6	2 km (1 mi) ENE of Obsidian Butte
4.3	2005/08/31 16:27:32	33 11.9 N 115 35.4 W 02.9	5 km (3 mi) NE of Obsidian Butte
4.5	2005/08/31 16:32:11	33 11.4 N 115 36.2 W 04.2	4 km (2 mi) NE of Obsidian Butte
4.0	2005/08/31 16:33:38	33 12.0 N 115 36.4 W 03.7	4 km (3 mi) NE of Obsidian Butte
4.4	2005/09/01 06:50:20	33 10.7 N 115 38.0 W 00.0	1 km (1 mi) NNE of Obsidian Butte
4.5	2005/09/01 18:27:18	33 10.5 N 115 37.9 W 04.9	1 km (0 mi) NE of Obsidian Butte
5.1	2005/09/01 18:27:19	33 09.6 N 115 38.2 W 09.8	1 km (1 mi) S of Obsidian Butte
4.7	2005/09/22 13:24:48	35 02.6 N 119 00.9 W 11.0	8 km (5 mi) WNW of Wheeler Ridge

One of the two largest earthquakes of the one-year period was a Mw5.2 in the Wheeler Ridge area on April 16. It was widely felt from the Fesno area on the north to northern San Diego Co. on the south. 2,815 people submitted reports to the CIIM (Community Internet Intensity Map) web site. Peak intensity was MMI IV. There were 44 aftershocks to this Mw5.2, the latest one on August 19. Another earthquake, ML4.7, occurred on September 22, as a slightly different location 5 miles west-northwest of Wheeler Ridge. This quake was felt from Visalia to Orange Co. and generated 3,948 CIIM responses. It had one foreshock (ML3.4) and 104 aftershocks up until October 1.

Another Mw5.2 earthquake occurred on June 12. This quake occurred in the Anza area, and was felt from Santa Barbara to Arizona. The CIIM site received 29,293 reports, showing a peak intensity of MMI VI in Anza, as well as in La Quinta and Coachella in the Coachella Valley. There were over 1,000 aftershocks, the exact number depending on the region selected.

The third largest earthquake, Mw5.1 on September 2, was a member of a healthy swarm in the northern Imperial Valley, which started on August 30 and continued through September 2, then at a steadily decreasing rate until about September 25. Nine of the magnitude 4+ quakes were members of this swarm. The Mw5.1 was felt widely (790 CIIM reports) as far away as Orange County & Twentynine Palms. Peak intensity reported was MMI VI, in Calipatria. Several other swarm members were felt in the Imperial Valley & surrounding areas. The total swarm membership was 1,062 earthquakes.

Several other earthquakes were widely felt, including:

A ML4.9 earthquake (the fourth largest quake of the reporting period) on June 16, located 2 miles northeast of Yucaipa, was felt from the U.S./Mexico border to Ridgecrest (15,890 CIIM reports, peak intensity VI in the epicentral area). There were approximately 100 aftershocks.

A ML3.9 on April 12, located 3 miles east of Jamul, in San Diego Co., was felt as far away as Borrego Springs and Orange Co. (5,062 CIIM reports with peak intensity of MMI V).

Processing of Backlog of SCSN Data

We have made more progress in processing earlier backlogs. Events from 1932 through 1976 now have computerized locations and magnitudes consistent with our current calibrations. All data from 1932 onward has been written to the Oracle database, although some time periods from 1977 to 1981 have not been completely processed. All of the CEDAR system data (1977 through 1980) that are readable from the tapes of that period have been translated from CEDAR format to CUSP & are being converted into the Oracle database.

The Southern California Earthquake Data Center

This center has significantly increased the use of the data from SCSN/CISN for scientific research. The SCEDC currently has 4.7 Tbytes of waveform storage in the form of 270,000

station-days of continuous recordings and 51.7 million triggered waveform segments. In the past year, we have shipped 2 Tbytes of waveform data each year.

These data, including 75 years of catalog, 75 years of parametric data, and 25 years of digital seismograms are available through the Internet in near-real-time.

Archiving of Earthquake Information

The SCEDC continuously archived high sample-rate data from:

- August 31 (00:00:00) to September 9th (00:00:00) for the 2005/08/31 M=4.6 and the 2005/09/02 M=5.2 Obsidian Butte events.
- June 12th (12:00:00) to June 18th (00:00:00) to capture foreshock/aftershock data for the 2005/06/12 M_w 5.2 Anza event and the 2005/06/16 M_w 4.9 Yucaipa event.
- Fontana Swarm: EVID: 14116972 Mag = 4.4
  Origin date/time: 2005/01/06 14:35:28, -2.5h, +21.5h. All stations within 50km radius of origin
- The half hour before and 5.5 hours following the December 26th M 9.0 Sumatran earthquake.

Statewide Network Integration

- Chaired the schema-change CISN working group which evaluates requests to change the NCEDC/TriNet database schemas. The working group has been evaluating and implementing medium- and low-priority requests for changes to the NCEDC/TriNet Parametric Information schema.
- Created a new Application Schema and submitted all documentation of it to Berkeley for inclusion in the Embarcadaro documentation site.
- Worked with the PMG and CISN partners to coordinate replication of NCEDC schema tables to facilitate the real-time sharing of station metadata and determine the impact of this operating this system in parallel with the Station Information System (SIS).
- Worked extensively with CGS to ensure that STP V0 format conforms to the COSMOS standard. Made significant code changes to STP to accommodate CGS requirements. This work will allow the CISN to transport waveform data in V0 format from the NCEDC and SCEDC CGS using STP.

Database

- Installed Oracle 10g client on test realtime server dacite.
- Installed post processing stored procedures on realtime databases. The motivation for this was to standardize how tables and their columns are populated, regardless of whether the transaction was from post-processing or realtime system. This way database queries would be more accurate.
- The Yucaipa and Anza events in June showed that public access to the database via the web, while small with low seismicity, can become the biggest consumer when there is an event of public interest. The SCEDC established a read-only database dedicated for public use on Aug 1.
- On June 13, the RAID on one of the production servers failed, bringing the database down and corrupting many database files. Access to database archive was uninterrupted as all data from realtime systems was directed to the other database server, makaludb.

Information Distribution and Product Development

Website

- Reorganized the SCEDC website and posted a site map at http://www.data.scec.org/sitemap.html. This webpage will allow Data Center users to navigate the site more easily, show available resources and outline the structure of the website.
- Developed a website for the scanned images of pre-digital analog recordings of major earthquakes recorded in Southern California between 1962 and 1992. Scanned images of paper records for M>3.5 southern California earthquakes and several significant teleseismic events are available for download via the SCEDC through this searchable system available at: http://www.data.scec.org/research/scans/. The web interface allows users to search the available files, select multiple files for download and then retrieve a zipped file containing the results.
- Created a new webpage for the release of the new Version 4 of the SCEC 3D Velocity Model at http://www.data.scec.org/3Dvelocity/. Worked with the developer of the Model to update previous documentation and provide a more thoroughly documented version of the current model.
- Released a searchable Moment Tensor Solution page at: http://www.data.scec.org/catalog_search/CMTsearch.php. The SCEDC is archiving and delivering Moment Magnitudes and Moment Tensor Solutions (MTS) produced by the SCSN in real-time and post-processing solutions for events spanning back to 1999.
- Created a one-stop download page for all Data Center software and products at: http://www.data.scec.org/research/downloads.html.
- Posted a webpage with brief descriptions of SEED channels acquired by the SCSN and their respective SCEDC archiving status at http://www.data.scec.org/stations/channeldesc.html.
- Created an automated sync-file request form at http://www.data.scec.org/sync/sync.html. The sync file format can be used by programs to compare the inventory of different data centers to determine whether data is missing at one of the centers.

STP

- Changed aliasing on STP servers to: stp -> logan.gps; stp2 -> k2.gps; stp3 -> makalu.gps to have users point at the read-only database on logan before accessing the primary production databases that are part of multi-master replication.
- Fixed a bug in the STP client that prevented it from being compiled with the newest version of gcc. Information about the bugfix is available at http://www.data.scec.org/ftp/programs/stp/BUGFIX_README.
- Modified STP to output parametric data in XML format: To output the results of a query in XML, the user simply types 'XML' at the STP prompt. To return to normal output, users type "NORM" The STP format will output the results of the phase and event command XML into a named file. The XML at the SCEDC homepage is http://www.data.scec.org/xml/.
- Developed a new STP Client - Version 1.4.1 for Macintosh: In response to requests from the user community, the SCEDC released an STP console client for the Macintosh. This client is virtually identical to the UNIX and Linux versions, but it operates in the Mac environment and allows users to download SCEDC data directly onto their Mac.
- Modified STP to output coda decay measurements for local earthquakes.
- Added an “-f,” output-to-file option to STP’s event search function to allow users to write the results of their search to a file.

Location Codes

- Updated continuous waveform requesting system on the Data Center to include location codes in the requests. Also updated the code that is used to generate continuous requests for high sample-rate data for significant events to include location codes in the requests.
- Updated continuous and triggered waveform archiving code to include location codes in the final archive.
- Introduction of station RVR with a second location code into database showed that request_card table needs to have its primary key constraint modified.

Station Information System (SIS)

- Data from broadband stations have been migrated to SIS database.
- New updates to data are done through SIS GUI (graphical user interface) in parallel with the legacy database.
- Dataless SEED volumes can now be generated against the SIS database. In addition to the SEED volumes for broadband station, the SIS now has the data to generate SEED volumes for USGS short period telemetered stations. This information does not exist in the current system.
- Views have been created against the SIS schema, which closely resemble current CISN station tables. Plans are for the post processing and realtime systems to use these tables once SIS goes into production. Put together a testing package for the administrative users of the SIS. The worksheet package contained scenarios for the users to work through to determine if any modifications were necessary to make the system work better for users and to familiarize the Admin users with all of the panels on the interface.
- Finalized version 1.0 of the SIS database schema. The end product is a well-documented, normalized database design.
- Developed a homepage for the SIS project at: http://www.data.scec.org/stations/SIS/, which includes project documentation and progress.
- Developed stored procedures for SIS as an API between applications and data model. By using stored procedures changes can be done on data model without requiring changes to the applications that access the database. Stored procedures include writing SEED volumes, inserting logger, sensor information into the database and modifying existing instruments.

Catalogs

- Added Google Earth and Google Map support to the catalog searches at http://www.data.scec.org/catalog_search/date_mag_loc.php. Users can download KML files containing the output of searches by event ID, polygon, radius, and date, magnitude, and location. When the KML files are opened in Google Earth, users can zoom in on locations of events down to a few meters above the ground and manipulate surrounding 3D-rendered terrain. If Google Map output is selected as the output format, the result of the catalog search is plotted on a Google Map.
- Posted Hardebeck's focal mechanisms from P-wave polarity and S/P amplitude ratios catalog at http://www.data.scec.org/research/socal_focal_JLH.html. The dataset includes more than 24,000 focal mechanisms for earthquakes occurring 1984 through 2003.
- Updated the alternate location catalog with new SHLK_1.01 and SHLK_IMP_1.0 data and updated http://www.data.scec.org/ftp/catalogs/SHLK/. When users query for all information from all catalogs from STP, they will get up to five data sources:

```
STP> altloc -e 9875225
  9875225 2002/12/31,21:59:57.670   33.1812   -115.6160   3.15  2.18  l SHLK_IMP2005
  9875225 2002/12/31,21:59:58.030   33.1753   -115.6120   3.65  2.18  l HAUK2003
```

```
  9875225 2002/12/31,21:59:58.540   33.1803   -115.6150   3.02  2.18  l SHLK2005
  9875225 2002/12/31,21:59:58.540   33.1960   -115.6208   1.77  2.18  l HAUK2004
  9875225 2002/12/31,21:59:58.920   33.1862   -115.6110   1.63  2.18  l SCSN
# Number of events= 5
```

- Modified the catalog search page to a new URL:
  http://www.data.scec.org/catalog_search/index_date_mag_loc.php
  The new page has a new look where most of the text is below the search form and also moved the Caltech and USGS logos to be more visible on the page. There are five tabs that will allow users to search by:
    1. Location, magnitude and time (default)
    2. Event ID (can be multiple comma-separated events)
    3. 4-point polygon
    4. Radius
    5. Multiple magnitude types for single events
- Added an option to the catalog search page to "Download to File" to accommodate XML output, as well as other catalog output formats.
- Worked with ISTI implement the IRIS DHI/FISSURES (Data Handling Interface) services. DHI provides well-defined standardized methods to remotely access information from the SCEDC. The DHI can be thought of as an Application Programming Interface (API) that can be used as a well-specified, standardized interface to any seismic data center. There are three different DHI servers installed at the SCEDC:
    1. **Network Server:** provides information about networks, stations, sites, channels, and responses. Most client applications will use either this server or the Event server before retrieving seismograms.
    2. **Event Server:** includes event origins, magnitudes, arrival times and channels.
    3. **Seismogram Servers:** This server provides for retrieval of seismograms.

  More information is available at http://www.data.scec.org/research/DHI.html.

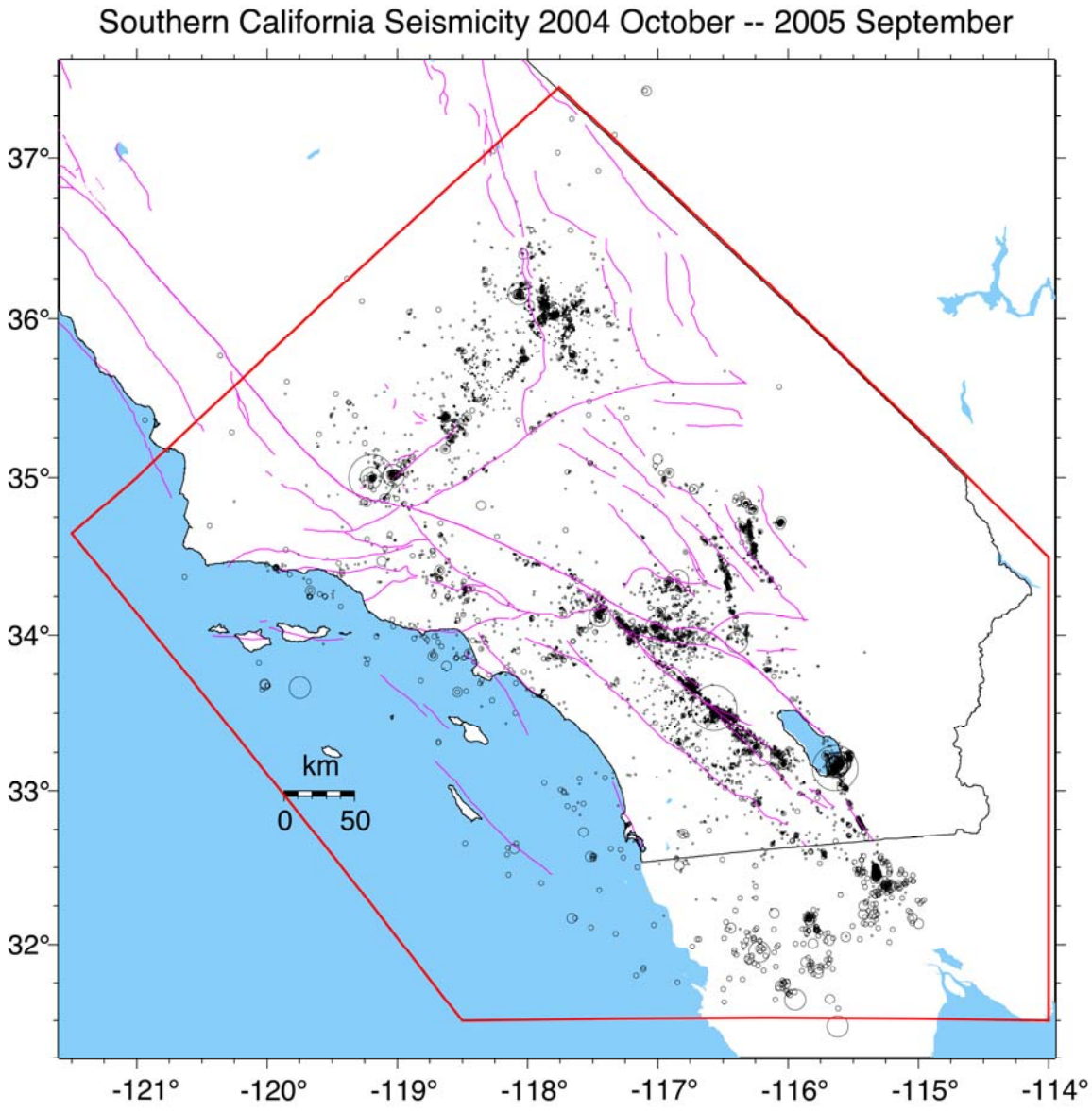

Figure 1. Southern California seismicity recorded by SCSN and archived by SCEDC: 1 Oct. 2004 to 30 Sept. 2005.

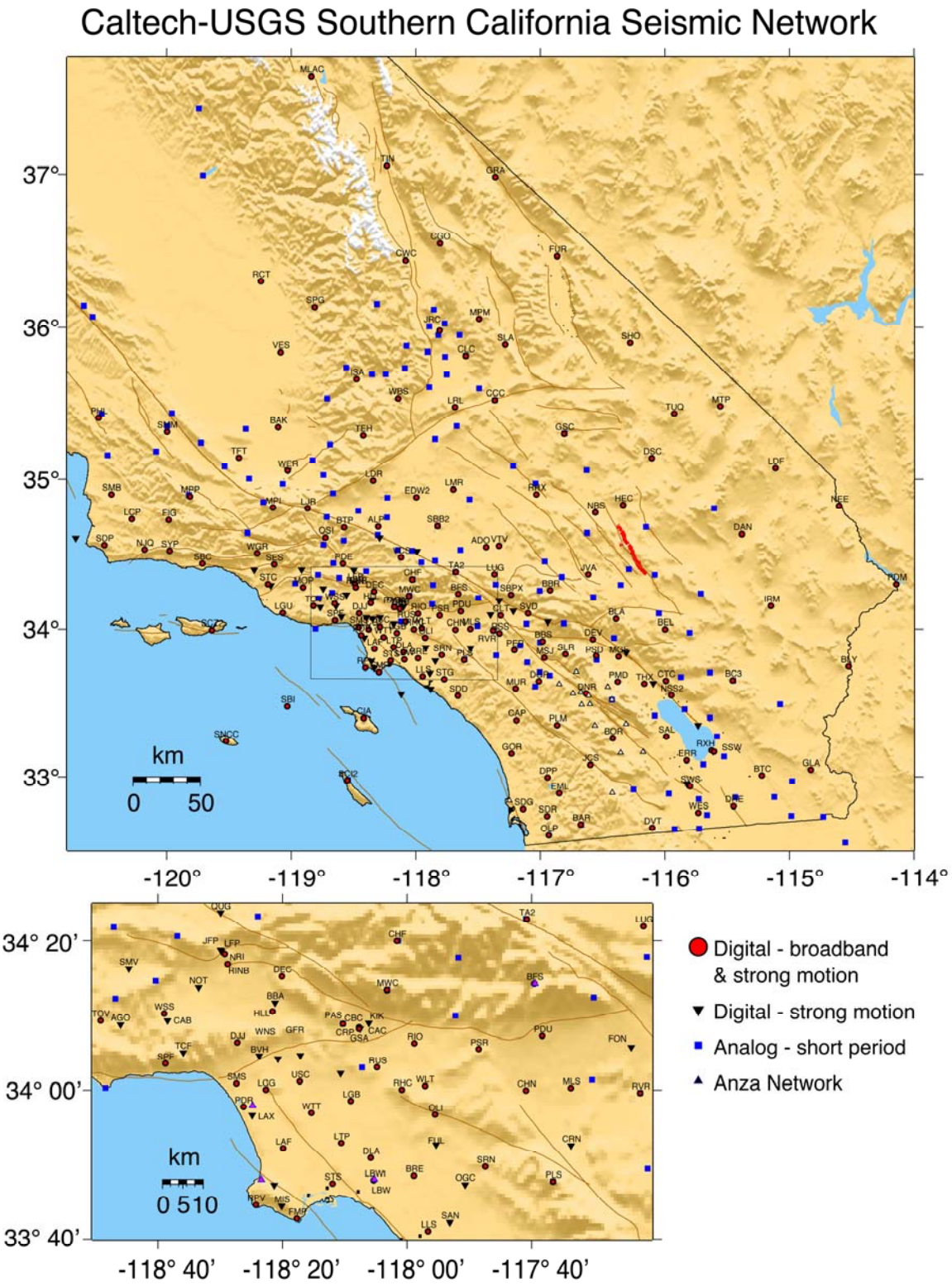

Figure 2. Southern California seismic stations recorded and operated by the SCSN. Not shown are an additional 50 stations recorded by SCSN but operated by other agencies.

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http://www.cisn.org

This Cooperative Agreement provides partial support for the joint USGS-Caltech monitoring of earthquakes in southern California. We recorded and analyzed data from more than 12,492 local earthquakes in FY2005. We also maintain field equipment located at remote sites and equipment and software at the central site in Pasadena. The primary product is a database of earthquake data, which includes a joint USGS-Caltech catalog of earthquakes in the southern California region. We also provide rapid response to emergency services, the media and public inquiries about earthquakes, and archive earthquake data at the Southern California Earthquake Data Center. For information about data access, please contact: Dr. Kate Hutton at (626) 395-6959.

NON-TECHNICAL SUMMARY